

Special Publication

CRYSTALLINE SILICA PRIMER

Staff, Branch of Industrial Minerals

**U.S. Department of the Interior
Manuel Lujan, Jr., Secretary**

**U.S. Bureau of Mines
T S Ary, Director**

Library of Congress Cataloging-in-Publication Data:

Crystalline silica primer/staff, Branch of Industrial Minerals.
(Special publication)
includes bibliographic references.
1. Silicate industry—Health aspects. 2. Silica-Toxicology.
3. Silica carcinogenicity. I. United States. Branch of
Industrial Minerals. II. Series: Special publication (United
States. Bureau of Mines)
RC965.S5C79 1992 615.9'25682-dc20 92-16938 CIP

PART I

Understanding Crystalline Silica?

Abstract	1
What is Silica?	2
<i>Silicon</i> Is an Element	2
<i>Silica</i> Is a Chemical Compound	2
<i>Silicates</i> Are Compounds of Silicon and Oxygen plus other elements	3
<i>Silicones</i> Are Synthetic Compounds	3
What Is Meant by Crystalline?	3
The Crystalline State	4
The Noncrystalline State	4
Focusing on Crystalline Silica	4
Crystalline Silica's Forms	5
Where Crystalline Silica Is Found	5
The Natural Occurrence of Crystalline Silica	5
In Igneous Rocks	6
In Sedimentary Rocks	6
In Metamorphic Rocks	6
Crystalline Silica in the Industrial Setting	6
The Many Uses of Crystalline Silica	6
In Glass, Ceramic, and Fine China Manufacturing	7
In Construction	7
In Heavy Industry	11
High-Tech Applications	11
Synthetic Crystalline Silica	11

PART II

The Regulation Of Crystalline Silica

OSHA's Hazard Communication Standard	12
The IARC Evaluation Process	13
IARC Classification of Silica	14
[Amended October 1996 by IARC]	15
Regulatory Activities of Other Agencies	16
The Complexities of Measurement	16
Conclusions	19
List of Resources and Selected Readings	19
Glossary	20

ILLUSTRATIONS

1. Terms Related to Crystalline Silica	NA
2. Silicon-Oxygen Tetrahedron	NA
3. Diatomite (amorphous) and Quartz (crystalline)	NA
4. Repeating Pattern of Crystalline Structure	NA
5. Random Pattern of Amorphous Structure	NA
6. Nonrepeating Patterns of Glassy Structures	NA

7.	Relationship Between Forms of Silica	NA
8.	Stability Fields of the Different Forms of Silica In Glass, Ceramic, and Fine China Manufacturing	NA
9.	The Geologic Cycle	NA
10.	The Glass making Process	NA
11.	Smithsonian Castle Built of Sandstone	NA
12.	Oil Rig	NA
13.	Quartz Clock	NA
14.	Synthetic Quartz Crystal	NA

[Illustrations are not available in the PDF version of the Crystalline Silica Primer. Contact Robert Virta at the U.S. Geological Survey for a copy of the complete report with illustrations.]

TABLES

1.	Silica in Commodities and End-Product Applications	8
2.	Common Products Containing 0.1 % or More Crystalline Silica	10
3.	Methods Used to Detect Quartz in a Sample	18

its crystalline state only.

Crystalline Silica's Forms

Crystalline silica exists in seven different forms or polymorphs, four of which are extremely rare. The three major forms, quartz, cristobalite, and tridymite, are stable at different temperatures. Within the three major forms, there are subdivisions. Geologists distinguish, for example, between alpha and beta quartz, noting that at 573 °C, quartz changes from one form to the other. Each of these subdivisions is stable under different thermal conditions. Foundry processes, the burning of waste materials, and other manufacturing procedures can create the kinds of conditions necessary for quartz to change form. In nature, quartz in its alpha, or low, form is most common, although both lightning strikes and meteorite impacts can change alpha quartz into keatite or coesite. Alpha quartz is abundant, found on every continent in large quantities. In fact, alpha quartz is so abundant and the other polymorphs of crystalline silica are so rare, some writers use the specific term quartz in place of the more general term *crystalline silica*.

Where Crystalline Silica Is Found

Crystalline silica, usually in the form of alpha quartz, is everywhere. It is in every part of every continent. It occurs plentifully in nature and is used commonly in industry.

The Natural Occurrence of Crystalline Silica

All soils contain at least trace amounts of crystalline silica in the form of quartz. It may have been part of the rock that weathered to form the soil, it may have been transported, or it may have crystallized from an amorphous (*that is, a noncrystalline*) silica that formed during the weathering process. Quartz is also the major component of sand and of dust in the air. Quartz is present in igneous rocks-but only those that contain excess silica. As magma cools, olivine, pyroxenes, amphiboles, feldspars, and micas form first. These minerals (*all silicates*) need silica to form, because silicates are made from silicon, oxygen, and a metal, usually one of the six most common metals. Quartz forms only if sufficient silicon and oxygen are left over after these silicates have formed. Nature's odds are stacked in quartz's favor, however. The fact that quartz is the second most common mineral in the world (*feldspar is most common*) indicates that plenty of silicon and oxygen were left over during the cooling process to allow ample quantities of quartz to form. In fact, the average quartz content of igneous rocks is 12%.

In geologic history, igneous rocks originated from magma, the material carried to the surface from the Earth's molten core. The other two types of rocks are sedimentary and metamorphic. Quartz is abundant in all three types of rock. It is one of Earth's primary building blocks.

The *rock cycle* describes the relationship between the three types of rock. Igneous rocks reflect activity (*heat and pressure*) beneath Earth's crust; metamorphic rocks reflect activity both beneath the crust and within and at the surface; and sedimentary rocks reflect conditions (*wind, water, and ice*) at the Earth's surface. Over geologic time, sedimentary rocks maybe altered by

understanding was limited by the technology of his time. The ancients believed quartz to be very deep-frozen ice, which could no longer be remelted. In fact, to prove this hypothesis, Pliny pointed out that quartz seemed to be found most frequently in the vicinity of glaciers. Although they may not have understood its true nature, early civilizations did understand its value as a gemstone. Today, quartz is used for a whole spectrum of products (Table 2) from high-technology applications in the electronics and optical fields to everyday uses in building and construction.

In Glass, Ceramic, and Fine China Manufacturing

One of the major uses of crystalline silica is as a raw material for glass manufacture. The first glass was probably made in Egypt more than 5,000 years ago. Today, the process has become highly refined. To ensure a very pure product, the specifications for glass are exceptionally stringent. A pure crystalline silica is used; the iron content must be less than 0.03%, and there are strict limits on the amounts of other impurities. Even the grain size of the crystals is specified. In the finished glass, the silica content must be at least 98.5%. Ceramics, porcelain, and fine china are made from finely ground crystalline silica, called *silica flour*.

In Construction

Building materials, such as concrete and dimension stone (sandstone, granite, and limestone are examples) contain crystalline silica in the form of quartz. Dimension stone is commonly used to build churches, government buildings, and monuments. In the Nation's capital, for example, the White House is built of sandstone, the Smithsonian Institution's original building of sandstone, the exterior of the Museum of Natural History of granite, and the Treasury building of granite and sandstone. Quartz is a component of cement, another technological development dating from ancient times. In the past, sandpaper and grinding wheels were made from quartz, and it was the primary abrasive used in sandblasting operations.

Quartz is also used as functional filler in plastics, rubber, and paint. In George Washington's time, it was the fashion to add sand to paint. Thus, the wooden exterior of Mount Vernon, Washington's home in Virginia, was painted with a sand-paint mixture to give it the look of stone.